Continental J. Engineering Sciences 9 (1): 50 - 59, 2014 ISSN: 2141 – 4068
© Wilolud Journals, 2014 http://www.wiloludjournal.com
Printed in Nigeria doi:10.5707/cjengsci.2014.9.1.50.59

THE EFFECTS OF PROCESS VARIABLES ON THE GRINDING OF IRON ORE

Nuhu, Steven Kuba
Department of Mineral and Petroleum Resources Engineering, School of Engineering, Plateau State Polytechnic, Barkin Ladi, P. M. B. 02023, Bukuru, Plateau State, Nigeria

ABSTRACT

Grinding is the highest energy consumer in all the unit processes of mineral beneficiation. The performance of grinding mills depends on many operating factors among which are the time of grinding, mill speed, grinding media–to-ore ratio, and filling ratio. These factors affect the fraction of energy from the total energy drawn by the mill system utilized in material size reduction. These variables were investigated in regard to the Itakpe iron ore. A representative sample of 10.5kg of the iron ore was collected and milled, taking appropriate quantities to study the process variables; the effect of grinding time, fraction of mill critical speed, media-to-ore ratio and mill filling. The results of the analyses clearly shows that using a sieve of +180μm and its bottom -180μm, the best time for grinding 0.5kg of Itakpe iron ore with 3kg of grinding media and a mill speed of 92 rpm is 8 minutes, yielding 17.10% fines and 82.90% coarse., 0.8 mill critical speed measured 15.20% fines and 84.80% coarse. Grinding media-to-ore ratio of 3:0.5kg gave 21.00% fines, 79.00% coarse and mill filling is 3kg:1kg of media and iron ore liberating 15.00% fines and 85.00% coarse.

KEYWORDS: Critical speed, Communition, Mill Filling, Grinding Media, Mill Speed, Beneficiation.

Received for Publication: 12/10/14 Accepted for Publication: 29/12/14
Corresponding Author: kubsteven3@gmail.com

INTRODUCTION

Since pre-historic time, minerals have played a major and important role in man's ways of life and development in general. However, modern civilization depends upon and necessitates the use of mineral in countless number of ways (Taggart, 2000). Metallic ores, industrial minerals and precious or gemstones are mined on every continent where there is considerable concentration sufficiently to be economically extracted (Concha, 2011). The measure of the development of any country depends on the production and utilization of mineral, most especially iron ore as raw material for technological development (Herbst, 2008).

Nigeria is blessed with large reserves of iron ore. The iron ore is being mined and processed as feed for the nation's steel plants at Ajaokuta and Aladja. The aim of grinding is to bring the ore to the mesh-of-grind (product size) required to obtain optimum liberation size in which the valuable mineral is just released from the ore matrix (Wright *et al*., 2001). Further grinding after the liberation size leads to waste of energy. The finer the ore is ground the more is this grinding cost (Wills, 2006). Up to a point, final recovery results in higher recovery values, but beyond this, over grinding leads to poor recovery since over grinding produces the particle size of the substantially liberated major constituent usually the gangue, and may reduce the particle size of the minor constituents usually the mineral value, below the size required for most efficient separation (Morrell *and Valery*, 2001). Optimum grind defines the mesh of grind (product size) at which a maximum profit is made on sales, when both the working cost and effects of grinding and the recovery of values have been brought into consideration (Lewis *et al*., 2006). Over-grinding needlessly reduces the particle size of the gangue and metal below the size required for efficient separation while under-grinding of ore will of course result in a product which is too coarse and be difficult to treat. Therefore, correct grinding is often said to be the key to good mineral processing (Jaspan, 2008).

The process variables on grinding of the iron ore such as time of grinding, speed of mill, mill fill etc which ultimately determines good liberation at optimum particle size which saves communition energy and facilitates mineral separation at lower costs (McIvor *and Finch*, 2006). Therefore, the results of the experiment conducted as revealed by this paper is hoped to go a long way in ensuring efficient grinding as a unit operation in the processing of iron ore.

Mineralogy and Magnetic Mineral Separation of Itakpe Iron Ore

The mineralogy analysis of an average sample of iron ore from Itakpe hill shows; 20% magnetite, hematite accounts for 30% and non-magnetic has 50% (McIvor *and Finch*, 2006). Magnetic mineral separations of Itakpe were made on four representative samples and the results shown as follow;

Table 1: Magnetic Mineral Separation of Itakpe Iron Ore

Sample	1	2	3	4
Magnetite	12	54	0.5	traces
Hematite	49	5	53	67
Non-magnetic	39	51	46.5	33

Source: (McIvor *and Finch*, 2006)

The Geochemistry of Itakpe Iron Ore

The chemical analysis of an average sample of iron ore from Itakpe hill revealed the following result.

Table 2: Geochemistry of Itakpe Iron Ore

Element/ Compound	Unit (%)	Element/ Compound	Unit (%)
Fe	35.00	CaO	1.25
SiO_2	42.05	Al_2O	3.20
TiO_2	0.17	CO_2	0.38
MgO	1.35	H_2O	0.41
P	0.095	Na_2O	0.52
Mn	0.75	K_2O	0.64
S	0.03	Pb	0.64
Zn	0.001	Cu	0.005

Source: (McIvor *and Finch*, 2006)

The aims of this research are to: determine optimum grinding time and mill speed that can give proper liberation of iron ore from its matrix, find the mill filling and grinding media-to-ore ratio in a grinding cylinder which gives correct particle size for effective beneficiation and determine good liberation at optimum size which saves comminution energy and facilitates mineral separation at lower cost.

METHODOLOGY

Materials/Equipment

Grinding is the last stage in the process of comminution, in this stage a combination of impact and abrasion reduces the particles size. In the process, particles less than 1mm are reduced in size to between 10 and 300µm (Magdalinovic, 2009).

The following apparatus and equipment played a great role in realizing the experiment or research. They include: weight balancing machine, grinding mill, grinding media, grinding cylinder, sieve shaker. Others are laboratory crusher, pulveriser, riffler and sieve (Rowland and Kjos, 2000).

Method

A total quantity of iron ore of 10.5 kg was split into equal parts using the riffler. One of these samples was used for screening on the +180 µm sieve placed on the shaker and ran for 30 minutes (reference sample). The laboratory ball mill was prepared by adding about 3 kg of the steel balls, adjusting the rotational speed of the mill to 0.6 of its critical speed. Four half-

kilogram samples of the ore for grinding were prepared. The first, second, third and fourth samples were ground for 2, 4, 8 and 16 minutes respectively. Each of the above batches was screened on the +180 μm sieve for 30 minutes and the products were recorded (Figure 1.0). For 8 minutes grind time and 0.6 mill critical speed the grinding media-to-ore ratio were subsequently changed; 3kg:1kg, 3kg:0.5kg, 3kg:0.25kg. These products were screened on +180 μm sieve and the results were reported (Figure 2.0). For 8 minutes grind time and fixed grinding media-to-ore ratio (3kg: 0.5 kg), the mill speeds were varied 0.3, 0.6, 0.8, 1.0 and 1.2 of its critical speed. The products were screened on +180m sieve and recorded (Figure 3.0). For 8 minutes grind time, 0.8 mill critical speed, the grinding media-to-ore ratio were fixed, and mill filling varied: 1.0kg:0.25 g, 2.0kg:0.5kg, 3.0kg:1.0kg, 4.0kg:1.5kg, 5.0kg:2.0kg. The products were screened on +180 μm sieve and results were reported (Figure 4.0). On separate graph sheets, the percentage +180 μm and -180 μm versus each of the variable were plotted (Abonzeid, 2000).

RESULTS

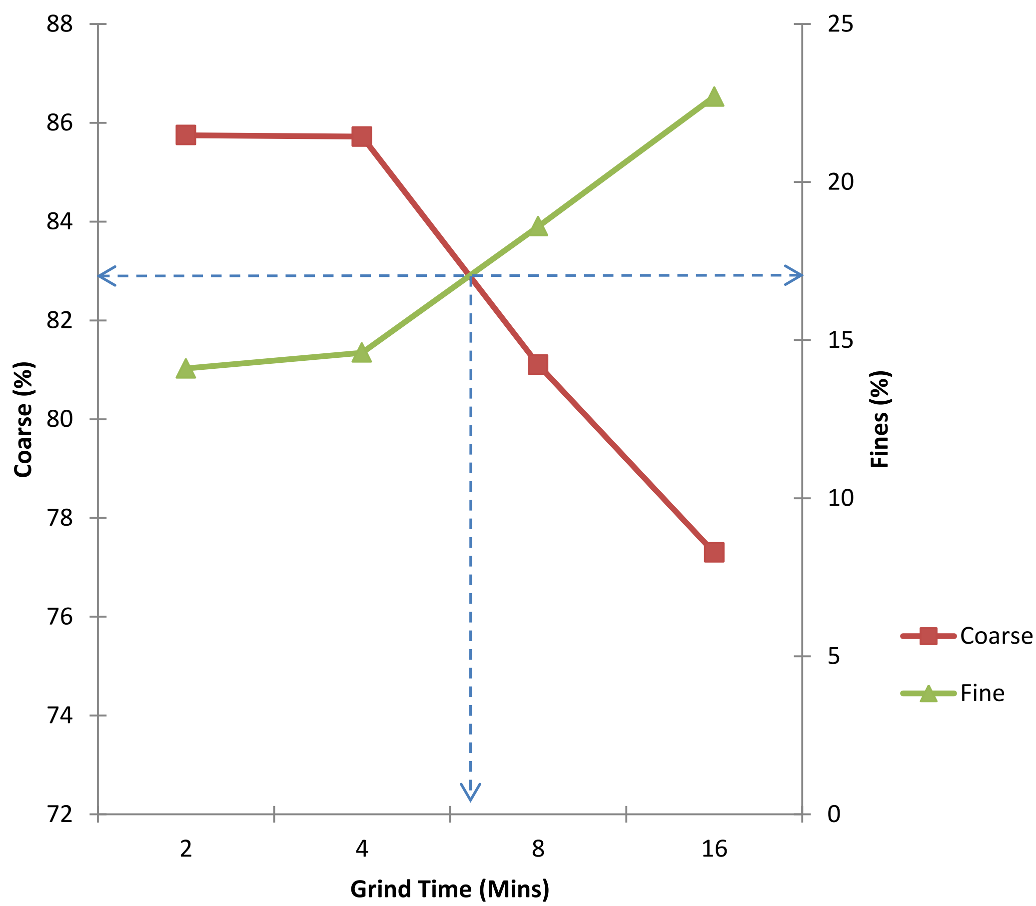

Figure 1: Effect of Grinding Time

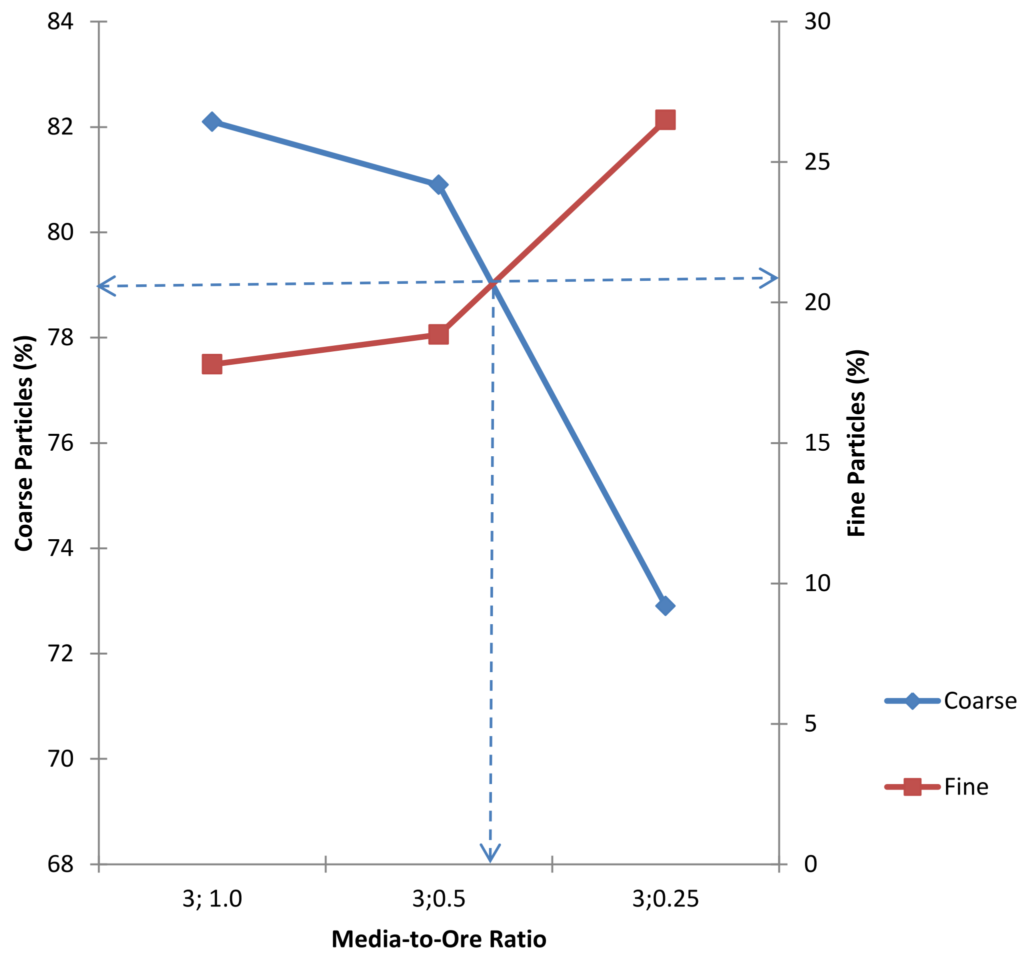

Figure 2: Effect of Grinding Media-Ore Ratio

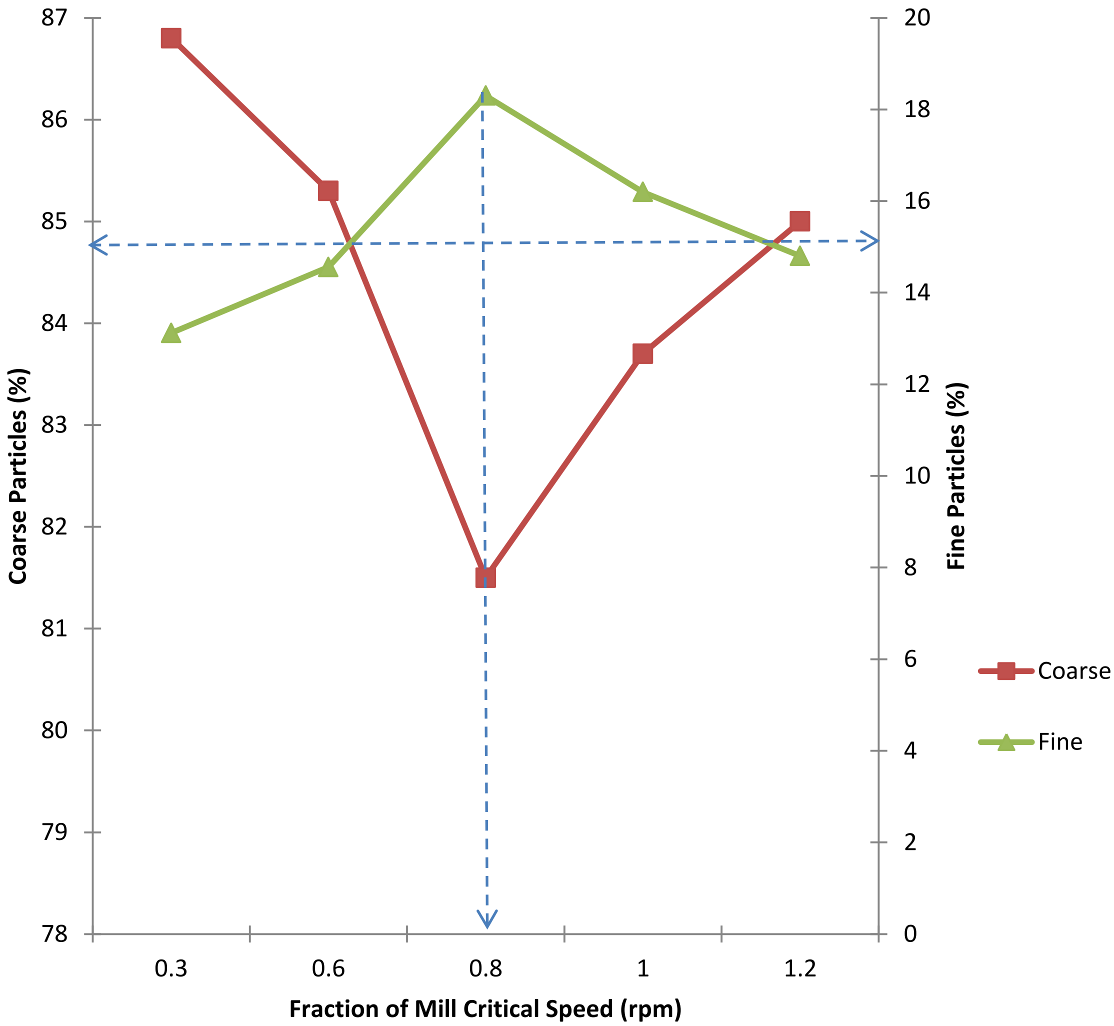

Figure 3: Effect of Fraction of Mill Critical Speed

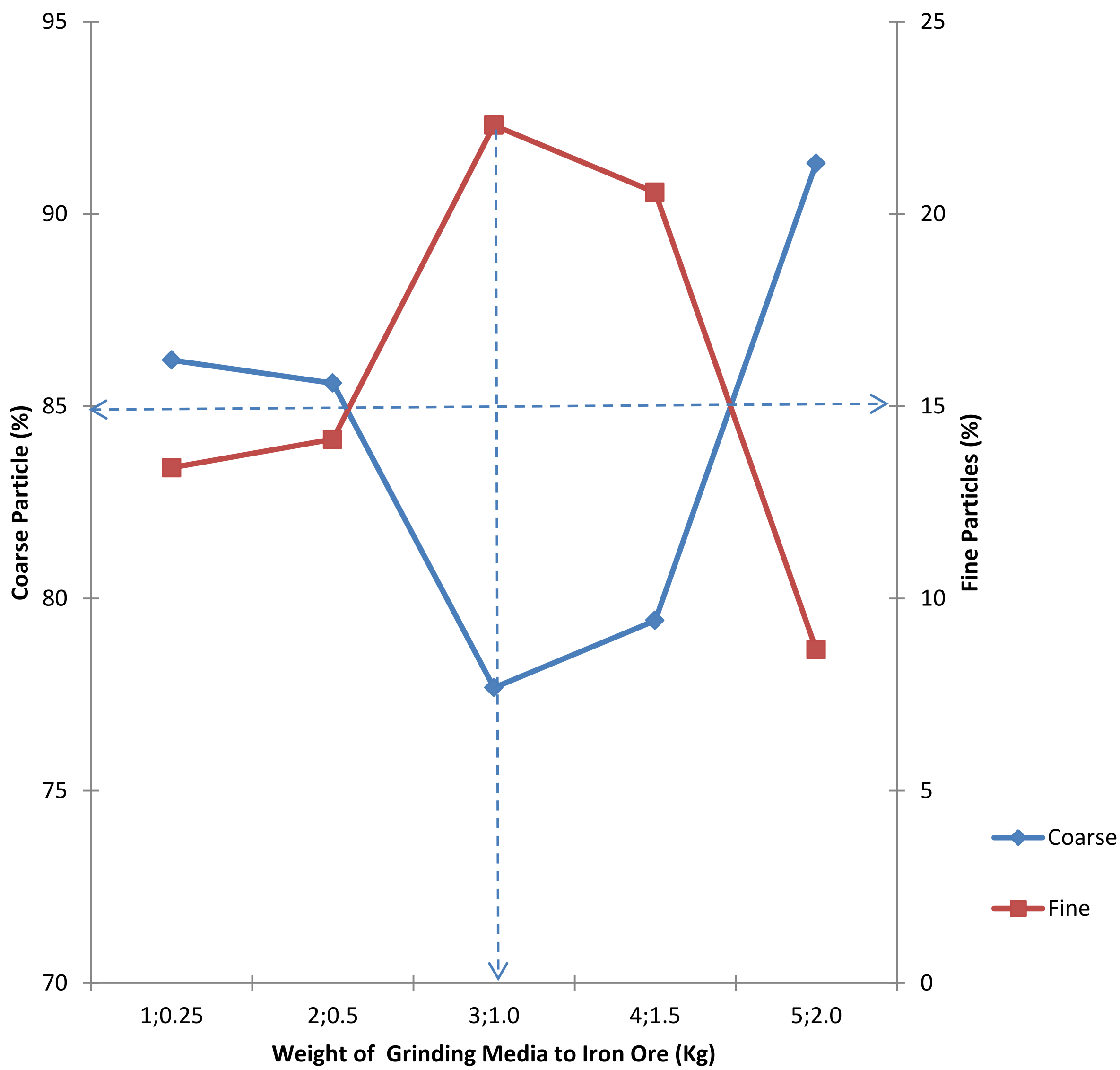

Figure 4: Effect of Mill Filling

DISCUSSION

From Figure 1, 3kg and 0.5kg were the fixed amounts of grinding media and iron ore respectively, varying the grinding time, it was observed that for 2 and 4 minutes grind time, 14.10% and 14.60% fines and 85.74% and 85.20% coarse were produced as the ore was ground. At 8 minutes, the fines escalated to 18.6% and at 16 minutes grind time the fines became 22.70%, bringing down the percent coarse to 81.10 and 77.30 respectively. From this trend, as

stated by Jones and Holmberg (2006), the more time taken to grind the ore, more fines and less coarse may be respectively produced. It is a fact that when reasonable fines are produced from the grinding of an ore the treatment or liberation becomes relatively easy, but when too much fines are produced the treatment becomes difficult because more of the valuable metal have been ground to slimes.

In Figure 2, where a fixed grinding time of 8 minutes and 3kg grinding media were maintained, changing the amount of iron ore only (1.0kg, 0.5kg and 0.25kg), the amounts of fines increased (17.80%, 18.86% and 26.50%) consequently decreasing the quantity of coarse (82.10%, 80.90% and 72.90). Further decrease of ore will bring about further decrease in coarse percentage with increase in the amount of fines. The possible way to correct this trend is probably by reducing the weight of the grinding media or increasing the quantity of ore.

Figure 3, gives 13.12%, 14.56% and 18.30% of fines at critical speeds of 0.3, 0.6 and 0.8 in that order, but with increased of critical speed to 1.0 and 1.2, the fines sharply diminished to 16.20% and 14.80%. Correspondingly, the value of coarse percentage decreased (86.80, 85.30% and 81.50%) with increased in the critical speed of the mill 1.0 and1.2, the coarse percentage began to rise (83.70% and 85.00%) again. Further increase of critical speed may increase the amount of the coarse percent, meaning, no adequate liberation took place, hence difficult to treat.

Lastly, in Figure 4, varying the weights of both the grinding media and the ore (1:0.25, 2:0.5, 3:1.0, 4:1.5 and 5:2.0), the results had it that the amounts of fines steadily increased (13.40%, 14.14% and 22.31%) with corresponding coarse decreasing (86.20%, 85.60% and 77.68%). However, immediately it passed 3:1.0 grinding media to ore ratio the percentages of the respective fines and coarse began to decrease and increase significantly (20.56% and 08.67%; 79.43% and 91.32%). From this, it can be deduced that the more the mill filling the better the liberation but to a point the more the mill filling the less the grinding effect.

CONCLUSION

The aim of this paper is to determine economical or optimum values at which the process variables in grinding an iron ore can be performed at low or minimal operating costs in terms of energy and time.

Therefore, the best speed for grinding in this mill will give optimum values as follows: in 8 minutes grinding time, 17.10% fines and 82.90% coarse will be obtained (Figure 1). At 0.8 mill critical speed, 15.20% fines and 84.80% coarse were measured (Figure 2). The grinding media to ore ratio at 3kg: 0.5kg will give fines up to 21.00% and coarse 79.00% (Figure 3). Finally, 15.00% made of fines and 85.00% coarse is a good liberation as determined by the mill filling (Figure 4).

REFERENCES

Abonzeid A. Z. M. (2000). Mineral Processing Laboratory Manual, Pg 66 -72, Published by Trans Technical Publications.

Concha, F. (20011). Optimization of the Ball Charge in a Tumbling Mill in Proc. XVI Int. Min. Proc. Cong. A, ed. K. S. E. Forssberg, Elsevier, Amsterdam, 147.

Herbst, J. A. (2008). Optimal Control of Comminution Operations. *International Journal of Mineral Processing* (Apr.), 275.

Jaspan, R. K. (2008). Run of Mine Mill Power Control Using Multiple Microphones to Determine Mill Load. Proc. Gold 100 Conf. SAIMM, Johannesburg.

Jones, S. M. and Holmberg, K. L. (2006). Modern Grinding Mill Designs in Changing Scopes in Mineral Processing. Edited by M. Kemal, A. A. Balkena. Rotterdam.

Lewis, F. M., Coburn, J. L. and Bhappu, R. B. (2006). Comminution: A Guide to Size Reduction System Design. *Mining Engineering Journal* 28 (Sept.). 29.

Magdalinovic, N. M. (2009). Calculation of Energy Required for Grinding in a Ball Mill. *International Journal of Mineral Processing* 25 (Jan.), 41.

McIvor, R. E. and Finch, J. A. (2006). The Effects of Design and Operation Variables on Rod Mill Performance. CIM Bulletin 79 (Nov.), 39.

Morrell, S and Valery, W. (2001). Influence of Feed Size on AG/SAG Mill Performance. Proceedings of SAG 2001 Conference, Vancouver, Canada. Vol. 1 348 – 36.1.

Morrell, S. and Kojovic, T. (2009). The Influence of Slurry Transport on the Power Draw of Autogenous and Semi-autogenous Mills, Proc. 2nd Int. Conf. on Autogenous and Semi-autogenous Grinding Technology, Vancouver, Canada 378.

Morrell, S. (2006). Power draw of Wet Tumbling Mills and its Relationship to Charge Dynamics,Trans. *Int. Min. Metallurgy*, 105, C43 – C62.

Nuhu, S. K. (2014). Grinding Analysis of Iron Ore: Carried Out in the Laboratory of National Metallurgical Development Council (NMDC) Jos. (Jan.).

Rowland, C.A. and Kjos, D. M. (2000). Rod and Ball Mills Mineral Processing Plant Design. 4thedition. Pg 242 – 243. Edited by Mular, A. L. & Bhappu, R. S. Published by SME of AIME, New York, U.S.A.

Taggart, A. F. (2000). A Hand Book of Mineral Dressing. 5th edition. Pg 60, 69 – 74, Published by John Willey and Sons, New York, U.S A.

Wills, B. A. (2006). Mineral Processing Technology. An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery. 7th edition. Published by Elsevier Ltd., U. K.

Wright, P., Hayward, N., Wilkie, G. and Sutherland, D. (2001). A Liberation Study of Autogenous and SAG Mills. Proceedings of Fourth Mill Operators Conference. AUSIMM, Burnie, Australia 171 – 174.